The Use of IoT in Crime Management

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***Abstract*— Crime has proven to be a prevalent problem in South Africa, with vehicle crime being among the most common crime issues. According to the vehicle tracking company, Tracker, while South Africa experienced a significant drop in vehicle crime during the lockdown set in place due to the global pandemic, the criminal activity seems to have increased back to normal since restrictions have been relaxed. The Internet of Things (IoT) is an emerging technology that could help combat these crimes. This project, in particular, involves the use of Global Positioning System (GPS) and crime data in order to map out places with high crime rates so as to alert drivers as well as the police station when they enter into those places, so that they take the necessary precautions to make themselves safe or stay alert – for example, calling someone to tell them that they are entering that particular area, driving a little faster, taking a different route or even avoiding that area altogether. This could significantly decrease incidences of muggings, shootings and car jackings. In this paper we look at pre-existing works and state of the art technologies, security and ethics related issues, the use of machine learning in the application and the data pipelining infrastructure. We then go on to detail the methods used in our application and then finally discuss our findings and possible future works.**

Keywords—Internet of Things (IoT), Vehicle Crime, Road Safety

I. INTRODUCTION

The Internet of Things (IoT) is the interconnectedness of devices across the internet. It is useful in the leveraging of data gathered by embedded sensors and actuators in machines and other physical objects [1]. It was coined in 1999 and has recently become relevant because of the growth of mobile devices, embedded and ubiquitous communication, cloud computing and data analytics [2]. It is also defined as the network of physical objects with limited computational power, storage, and communication capabilities. These are also embedded with electronics such as sensors, software and network connectivity which allows for the collection, processing and exchange of data [3]. IoT has various applications, and can be applied to solve many problems. Among the many, is the issue of road safety. Road safety is a prevalent problem in many parts of the world, including South Africa and vehicle related crimes seem to be among the most problematic. The company, Tracker, reported that while South Africa experienced a significant drop in vehicle crime during the lockdown, hijacking stayed prevalent and now that restrictions have been relaxed, criminal activity has begun to rise again [4]. Tracker's statistics indicate that, before lockdown vehicle crime activities increased by 11% nationally and hijacking was the most prominent activity on the list increasing by 21% while vehicle theft remained the same as last year [4]. During the month of April in lockdown level 5, vehicle crimes declined to 19% of the average monthly occurrence of these crimes but as soon as the restrictions were eased there was an increase up to 62%, and then in June it rose back to its usual levels of 93% [4]. In this paper, we propose an application that alerts drivers when they enter places with a high crime rate so that drivers can take the necessary precautions to protect themselves in case of an attack. This application will make use of crime statistics as well as the GPS sensor on a smartphone. We will look, specifically, at two vehicle crimes; hijacking and vehicle theft.

II. LITERATURE REVIEW

We will begin by looking at previous works involving IoT that are similar to our project. We look at state of the art technologies, machine learning methods, security and ethics related issues and the data pipelining infrastructure.

A. State of the art technologies

State of the art technologies include crime mapping applications in smart cities, road safety in smart cities using IoT, and traffic safety monitoring applications using IoT.

Smart Cities and IoT

Kim et al. conducted a research about smart cities. They found that Internet of Things (IoT) applications are mobilising "smart city" initiatives worldwide. They come with the ability to monitor remotely, manage and control devices, and come with new insight and useful information from massive streams of real-time data [5]. The main features of a smart city include a high number of data/information technology integration and a comprehensive application for managing data resources. The essential components of urban development for a smart city should include smart technology, smart industry, smart services, smart management and smart life [5]. The Internet of Things is about installing sensors (RFID, IR, GPS, laser scanners, etc.) for everything, and connecting them to the internet through specific protocols for information exchange and communications, in order to achieve intelligent recognition, location, tracking, monitoring and management [5].

With the support of the city ICT department, smart cities need to have these three features: being instrumented, interconnected and intelligent [5]. Only when a city shows these features can a "smart city" be formed by integrating all these intelligent features upon significant advances in IoT. The exponential growth in the number of "smart cities and IoT applications raises many scientific and engineering obstacles that invite research efforts from academia and industry professionals, especially for the development of efficient, scalable, and reliable smart city based on IoT [5]. New protocols, architectures, and services are in demand amid plans to respond to challenges of smart city development initiatives. The goal of the research was to invite and unite scholars, professors, researchers, engineers and administrators resorting to the state-of-the-art technologies and ideas to significantly improve the field of smart city based on IoT [5].

The Influence of Street Networks on the Patterning of Property Offenses

Beavon et al. performed a study about the influence of street networks on the patterning of property offenses [6]. The results of this study show that the risks of criminal ventures differ depending on their location. It was demonstrated that ventures are more likely to be undertaken if they are on relatively accessible and frequently used streets. The findings support the theory that property thieves show a patterned search behaviour in the selection of their targets with regards to the spaces they tend to occupy [6]. Criminals commit crimes within spaces they are routinely active in. This means that on average crime related to property is most likely to occur on streets which are highly accessible within the road network, have bad traffic or many commuters, and consist of places that are attractive to criminals such as flats, taverns, schools or hotels [6]. In the analysis of crime relating to property, ventures in highly accessible areas dominate the trend of criminal events.

The study provides knowledge that may be very useful to cities in their bid to reduce the rate of crime; there are decisions to be made about introducing barriers on roads [6]. In the relevant cities and parts of the cities that are not in development but fully developed, using traffic barriers effectively for the prevention of crime depends on using crime analysis relating to situations mindfully [6]. It is important to determine the crime patterns, to identify the potential criminals in the area of interest, and to examine the root cause of their criminal behaviour. It is particularly important to analyse how these offenders roam around the city areas in general and particularly in the area of interest. In an area that is high in crime, where most criminals reside near the places in which they undertake their ventures and in which most commuters dominantly walk, car traffic barriers will have an insignificant effect [6]. Using traffic barriers to reduce accessibility to areas with low crime rates will also have insignificant effect. Limiting car access to an area will only have impact if there is crime on roads other than main roads and crime is mostly committed by individuals who are not residents of the particular area [6]. Limiting access to non-arterial roads would likely reduce crime rates in the area; it certainly would not reduce crimes already occurring on or near main roads.

The initiative of reducing property crime through road design and area accessibility management should potentially have its greatest impact in the planning and development new resident areas. The road network can, if properly designed, deter commuters from outside the area without the use of boundary walls or gates. A road network that is well designed can even have a good impact on the network of travellers relating to local residents, both pedestrians and motor vehicle drivers. Pedestrian crossing in new areas should be considered as part of the general road network, particularly for children and adolescents, at the design stage. Because criminal behaviour peaks at a young age, opportunistic crimes may be highly related to travel paths for youth.

Through planning and development decisions, cities group together criminal targets and manage access to them; access restrictions vary depending on analysis metrics. Cities create the backdrop for crime through their control of routes, commercial developments, housing, building costs and transportation networks [6]. Pedestrians are likely victims of a different type of crime to that which is predominant to drivers and passengers of public transport [6]. Roadblocks to create dead-ends and manage traffic flow may reduce residential crime committed by individuals residing outside the neighbourhood and whom are travelling by motor vehicles, but not crime committed by the youth of the residential area that is roaming around the streets on foot [6]. The clustering of low income residents' houses on arterial roads may increase endeavors for crime and the rate of crime as a result [6]. In order for the effective reduction of crime, roads and the placement of all mentioned criminal targets should be analysed and solutions should be discussed to avoid potential crime ventures in the planning of new developments [6].

B. Role of Machine Learning in the project.

The data produced by IoT devices is immense, which means traditional means of the data collection, storage and processing of this data may prove useless at this scale [3]. Therefore, machine learning can be used to provide embedded intelligence in the IoT devices [3]. Machines and smart devices can infer knowledge from human-generated or machine-generated data with the help of machine learning. Since IoT is a great source of data or involves the collection of data, data science will allow IoT applications to be more intelligent. Data science involves data mining, machine learning and other techniques to find patterns and insights from data [7]. These techniques include a range of algorithms that can be applied in many domains. Applying data analytics to different domains involves the use of data models such as classification models, neural networks and clustering methods, as well as defining data types such as volume, variety and velocity; and the application of algorithms that match with the data characteristics [7]. We will look at various different crime and road safety related projects that have previously been done, and how machine learning was implemented in them if implemented at all, and then finally we will look at how machine learning will play a role in this particular project.

Identification of Crime and Accidental Area Using IoT

Prakash et al did a project on the identification of crime and accident areas using IoT. In this paper, they propose a system where they analyse 'black spots' which are areas where accidents or crime take place frequently on the road [8]. The analysis of the 'black spot' allows for the identification of what may be causing frequent accidents in that particular place [8]. They apply statistics analysis and data mining algorithms on a dataset called the Fatal Accident dataset to address this problem [8]. They use association rule mining to identify the cause of the road accident. How the system works is; an admin could add the police onto the system, where they can view the accident spot, apply the algorithm to that spot, and then decide how dangerous that particular spot is. A data mining algorithm takes accident level count to cluster the locations. Then they use geofencing and association rule mining to identify these locations [8]. The rules show different factors associated with the accidents at different locations. They used accident data issued from the Nasik city commissioner office [8]. The system uses the accident data, association rules, classification model and clusters obtained to make safe driving suggestions. It makes use of GPS and Global System for Mobile communication (GSM). The GPS is used to show the coordinates of the accident and crime spots on a map and send a voice notification when a driver or user is near a classified black spot [8]. The GSM is used to inform nearby emergency systems of the exact location of the vehicle. This project relies on the use of data mining algorithms, and while data mining is not machine learning – because businesses in the future could become more predictive, there is a chance of an overlap between data mining and machine learning. Machine learning algorithms could be used to improve data mining algorithms. For the association rule mining, perhaps learning techniques could be used to show the relationship between a new occurrence of an accident and the place of its occurrence.

Characterization of Road Accident Locations using Data Mining

Kumar et al., look at association rule mining to characterize road accident locations. Association rule mining is a common data mining technique that allows for the identification of the correlation in numerous attributes of a road accident [9]. Analysing these locations could help in identifying features of the road accident that make it occur frequently at a particular location. They apply a k-means clustering algorithm to group the accident locations into three groups, high-frequency, moderate-frequency and low-frequency accident locations [9]. The k-means algorithm clusters the locations using frequency as a parameter. Then association rule mining is applied to describe these locations [9]. They noted that intersections on highways are dangerous for every type of accident, using the association rules for high-frequency accidents. Locations with a higher frequency of mostly had accidents involving vehicles with two wheels, for example, motorbikes and bicycles, at regions with hills [9]. Moderate-frequency accident locations were found to be at colonies near local roads and highway road intersections, these accidents involved mostly pedestrians [9]. Locations with low-frequency accidents were found to be scattered throughout the district and were mostly not critical accidents [9].

Clustering is an unsupervised data mining technique that groups data objects into clusters based on similarity, such that objects in one group are more similar to each other than the other clusters. The k-means algorithm is a popular clustering technique for numerical data. It groups the number of objects into a particular number of clusters, k [9].

The dataset they use in this paper consists of 15574 road accidents from the period 2009 to 2014 in Dehradun District of Uttarakhand State in India but only 9640 accident records were considered for the research. The data was obtained from the Emergency Management Research Institute (GVK-EMRI) [9].

Crime Mapping in Nigeria Using Geographic Information System

Balogun et al. explore the possibility of using a geographic information system (GIS) to map and effectively manage crime in Nigeria. They do this by showing the procedural method of creating a digital map showing the crime locations, a crime geo-spatial database and spatial analysis such as query and buffering using ILWIS and ArcGIS software and GPS [10]. They are able to show crime hotspots, places that need constant police patrol, areas deficient in security, and areas of overlap. The paper looks at Benin metropolis as a case study. They mention the growth of the population in the city being responsible in the growth of crime activity as well – and mention that law enforcement agencies are becoming helpless and the non-use of GIS and geodatabase in the fight of crime is quite costly [10]. Knowing the location of where crimes mostly take place proves useful in combating it, and this is what GIS is responsible for. GIS software can combine multiple data layers to produce meaningful output and a single visual output [10]. GIS also allows the integration and analysis of data to identify suspects, leading to their apprehension and prosecution; it helps in effective allocation of resources and better policy setting [11]. Likely sensitive points in a hotspot area could be predicted using thematic maps. In this paper, they follow two methodologies. First, they distributed 66 questionnaires to the Police Public Relations Officers (PPRO) and 250 were distributed to the public [10]. The second was a look at how GIS could be used to manage crime using the spatial and attribute data collected from the field [10].

They were able to get results that support the use of GIS for effective crime control in the city. They note the ineffectiveness of keeping records in analogue form for crime analysis. Using GIS allows crime analysts to identify crime hotspots and other trends and patterns in order to formulate strategies to combat the crimes [10].

Since our project makes use of data, the use of data mining algorithms could be used to increase its efficiency. Classification algorithms could be applied to classify the different crimes that take place, the severity of the crimes and the causes of them. Going further, the system could be expanded to be used in various other places, and machine learning could be used in helping identify the likelihood of a crime happening in a certain place based on learning the relationship between a particular place and the crime taking place. Furthermore, new routes could be suggested for the user of the system if a route they take is deemed to be dangerous, and the likelihood of the other suggested routes being dangerous could be presented to the user as they approach those routes.

C. Security and Ethics Related Issues

Every project presents ethical concerns, and in the case of IoT applications, it would be the issue of whether or not people's data is safe when they use the application.
IoT consists of many data-producing devices and data-consuming applications that run physical devices on an optional basis. Some of this data is subject to privacy, such as heart rate and patterns of home occupancy. More specifically, we are seeing the creation of application frameworks that enable third-party developers to create applications that compute this data – Samsung Smart Things [12], Google Brillo/Weave [13], Vera [14], and Apple Home-Kit[15] are among a few examples.
In IoT applications, users usually have no choice but to trust that the application will not misuse their data and permissions. For our application, we intend to devise a strategy that will allow the application to make its data usage patterns transparent.

In our application, special attention will be paid to the handling of our user data. We will do this to ensure that there are no liability issues and that there is full transparency at all stages of working with the data as well as consent of the user. Since our application aims to identify areas of crime using location through GPS, it falls under the category of higher-risk data. As a result, a thorough review will be given of the ethical problems posed by the product

Related Work

Permission Models: It was noticed that IoT framework permissions are based on smartphone permissions. Major research efforts have been made to analyze and improve identity management in mobile phone frameworks [16]. For example, Enck et al. came up with the concept that dangerous permission configurations are suggestive of potentially malicious activity [16]. Roesner et al. implemented user-driven access control, whereby applications only seek permissions if they need it [17][18].

D. Data Pipelining Infrastructure

Before we can jump into an IoT data pipeline, we will first discuss what data pipeline is. A data pipeline is when certain actions are performed to extract data from various sources, to perform some analysis, and store it in the same format[19]. Or it can be the efficient stream of data from one area to the other — from a SaaS application to a data warehouse, and it is one of the most critical operations in today's virtual world. After all, a valuable examination cannot start until the data gets to be accessible. Data flow can be unstable, since there are so many things that can go wrong during the transportation from one system to another: data can end up being corrupted, it can hit bottlenecks (causing inactivity), or data sources may struggle and/or produce duplicates. A data pipeline can further be explained using the following categories: Ingestion, Transport, Storage and Management, Processing and Visualization. The pipeline architecture could change depending on whether or not the data is streaming or batch. For our project, we will focus on streaming data as well as routing it to devices. The data used is collected from a SAPS report [20], which shows data from different police stations in the Western Cape.

We aim to integrate some of the techniques mentioned above in the previous works into our project.

III. Methodology

In this section we detail how we implemented our idea and some of the errors we encountered, and how we fixed those errors if applicable.

A. Requirements Analysis

A set of requirements is needed for the successful operation of this project. Detailed below are those requirements.

Functional Requirements

- Requires the use of Google Maps to pinpoint locations.
- A database to store the user data (registration details, location)
- Protection of data of the user – the user data needs to be protected, and their permissions not misused.
- User-friendly interface – we need to ensure that the user does not find the application annoying or difficult to use. The application is meant to also be used in emergency situations and so navigating it should not be complicated.

Technical Requirements

- A smartphone (with enabled GPS sensor)

Operational Requirements

- The application needs to work quickly with no lag.
- The sending of alert messages has to be quick.
- Retrieval of location data has to be quick.
- We need to find a way to optimize the application so that it does not use a massive amount of power, therefore draining the battery of the device.

B. Architecture

The application works by sensing the location of a vehicle via the GPS tracking system on your smartphone. It warns you whenever it detects that you are nearing an area that is known for crime and alerts you that you are nearing a danger zone. If you are anticipating an attack, or being attacked – then you can click a button that allows you to send an alert message to ask for help to another device with the application installed.

The application makes use of the google maps API, which provides a world map allowing us to extract our region of interest. For this application, the Western Cape (Cape Town) was the region of interest. The map is then filtered to retrieve the points of interest (these are the places with the crime). The Google Maps API functions also locate the device being used. The API triggers the AndroidLocator API which is configured to use the android sensors.

It also makes use of Google Firebase as the database, which logs the location data of the crime areas, and the user's location. It also stores a user's registration details. When the user presses the "get help" button, Firebase Cloud Messages (FCM) is used to send out a notification to another device with the same application, to call for help.

C. Design

Device/Sensing Layer

The sensor used in the application is the GPS sensor on a smartphone. GPS is a radio navigation system. It uses the a receiver on your phone and radio waves between satellites to pinpoint the location and time of your device and provide that information to any software that needs it [21]. The receiver chip on your phone determines which satellites are accessible (i.e not hidden) to you and then gathers data from the satellites with the strongest signals [21]. The receiver on your phone uses data from the signals from four satellites required for GPS to work, and triangulates your location and the time [21].

Networking Layer

A star network topology is used, where multiple devices are connected to each other through a central server. The devices are connected to each other over the internet. When a user clicks the alert button to send a message requesting for help, Firebase Cloud Messages (FCM) is triggered which uses the Internet to communicate messages between devices. Sending notifications requires a Hyper Text Transfer Protocol (HTTP) post request to the FCM server, and the server then routes the notification to the targeted device. FCM allows you to reliably deliver messages between devices at no cost.

Middleware layer

Google Firebase allows for the synchronization of real-time data to the backend and the map. Firebase is used as our backend to store the coordinates of each danger zone or place of high crime activity as well as the coordinates of the place from where the application is accessed.

The database also stores user login details when they register into the application, so that the next time they want to use it – they do not have to re-register.

Application Layer

The mobile application on your smartphone, is the application layer.

People and Process Layer

The application is designed with the stakeholders as the commuters that will use the application, as well as the people on the receiving end of the alert messages (this could be the police, or a person that has the same application in the same area as you.)

IV. Results

Below are images detailing the working of the application.

Tools

- Flutter
- Google Firebase
- Google Maps API
- Android Studio

Fig. 1. Landing page after login

The user is met with this page as soon as they sign in, and they can click "Start Detecting" to begin looking for the high crime areas.

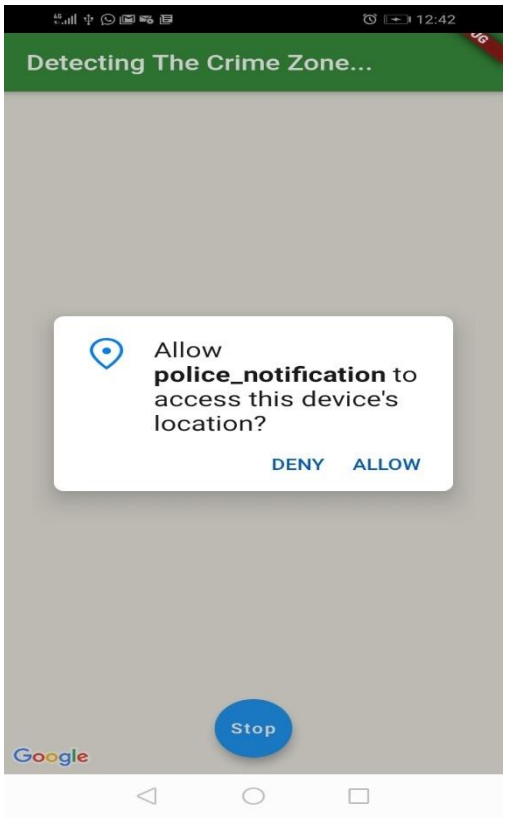

Fig. 2. Permissions prompt

The user is prompted for permissions.

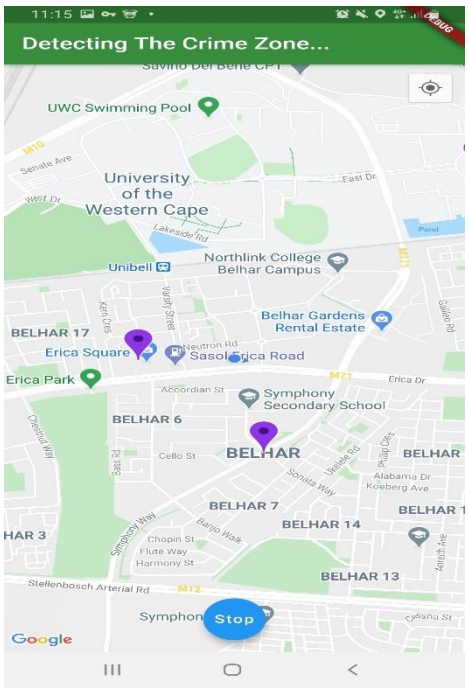

Fig. 3. Map showing danger zones

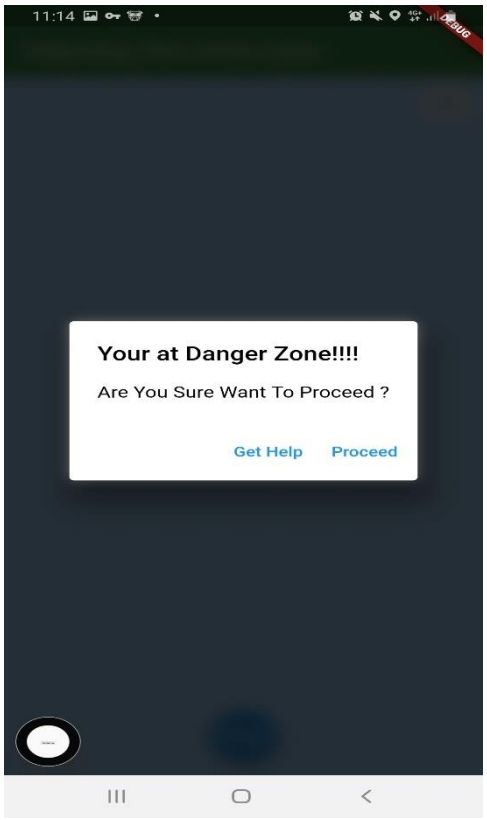

Fig. 4. Prompt to get help or proceed

The user sees the map, where the purple markers represent the dangerous areas. When they reach one, they are met with Fig.4 where they can either proceed, or press “Get Help” if they anticipate an attack.

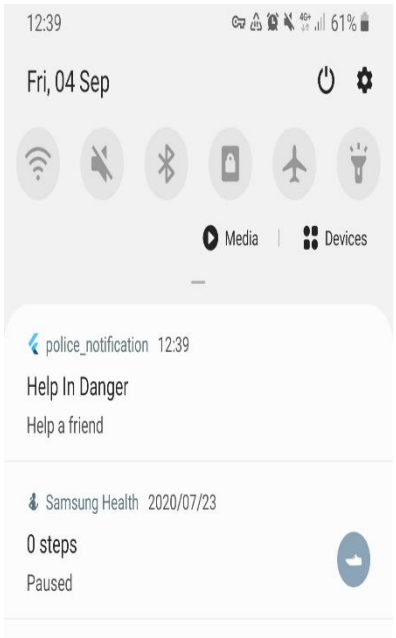

Fig. 5. The message sent to the other device.

The message sent when a user presses “Get Help” is sent as a notification like in Fig.5

V. Discussion

Business Value

Like most crime alert applications, an application of this kind would be free and so money would be made by the developers through advertising on the app.

However, in that case, we would have to take into account the ethics involved in that – and avoid selling user data to third party applications.

The application presents the possibility of decreasing fatalities as a result of crime, because if a notification is received as soon as the crime happens – help will be there quicker. Because the application warns a user of a danger zone, they can completely avoid that place altogether.

Use Case

Below is the use case diagram showing how a user would use the application. The user starts the trip and the application starts calculating the distance between the user and a crime zone. When the user is nearing the crime zone, the application alerts the user and asks whether they want to continue with the trip or not. If the user reaches the crime zone, the application alerts the user that they have reached the crime zone, and if they anticipate danger, there is a button they can press to alert the police (with the application on their device) about the danger.

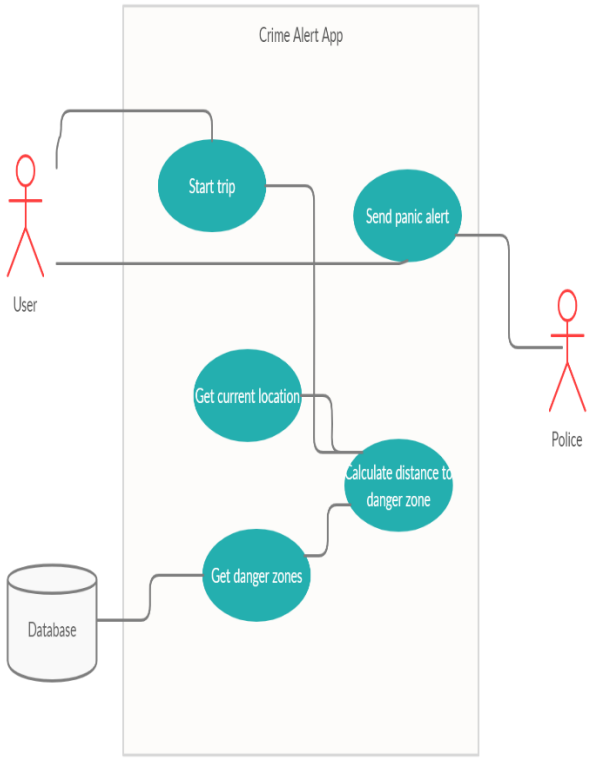

Fig. 6. Use Case Diagram

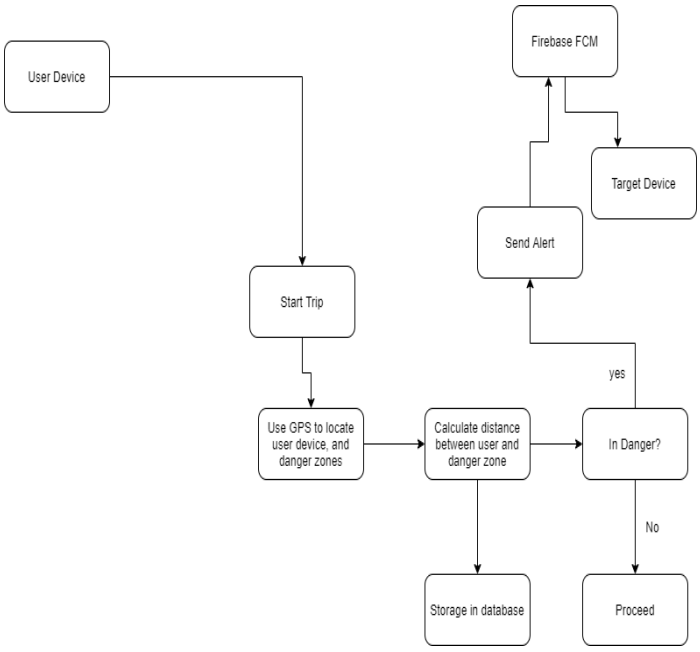

Fig. 7. Flow of events

Experience

One of the major challenges was having to learn how to use Flutter from scratch, because none of us in the team had prior experience with it. We also dealt with challenges of not being able to communicate effectively with each other because of the distance between us, and the misinterpretation that comes with texting. We all worked on the development of the application, assigning small research tasks to be completed by each of the team members and then integrated those into the final application.

VI. Future Works

In future implementations of the project, we would like to include machine learning in the application to predict when a crime is likely to happen at a particular area, based on data gathered about crimes in that area. We would also like to include an option to show alternative routes for the user, so that they can avoid an area with high crime rates if they wish to. Another possible feature, would be to include an external button that works with the application, that works with Bluetooth Low Energy (BLE) or Google Nearby API to allow users to call for help from the nearest devices around them.

VII. Conclusion

There is still a lot to consider regarding the building of this application and making it for real world consumption, for example, the cost of making an application like this and how

much work and manpower would be needed to make sure that it works well. The application presents the possibility of decreasing fatalities as a result of crime and even crime in general, because if a notification is received as soon as the crime happens, and the location of the person in danger is sent out, then help will be there quicker. It would be a helpful application to use to aid police services in getting the coordinates of where a crime is taking place, and could even be further expanded to include the functionality to call any emergency service, for any emergency.

The final implementation of this project, as well as a video demonstrating how the application works is available on here: https://github.com/CS-UWC/20-Moja
Demo: https://youtu.be/-1ZTfKwJYts
Project site: https://mojagroup.github.io/mojagroupsite/

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